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SEISMIC ANALYSIS OF MULTI STOREYED BUILDING WITH SOFT STOREY

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ABSTRACT

Earthquake in different parts of the world demonstrated the hazardous consequences and vulnerability of inadequate structures. Soft storey is a storey in which the stiffness is less than 70% of the storey above or less than 80% of the combined stiffness of the storey's above. In a multi-storied building, soft storey is adopted to accommodate parking which is an unavoidable feature. This open ground storey is vulnerable to collapse during earthquake. Soft storey in a building causes stiffness irregularity in a structure. In high rise building or multi storey building, soft storey construction is a typical feature because of urbanization and the space occupancy considerations. These provisions reduce the stiffness of the lateral load resisting system and a progressive collapse becomes unavoidable in a severe earthquake for such buildings due to soft storey. This storey level containing the concrete columns which were unable to provide adequate shear resistance, hence damage and collapse are most often observed in soft story buildings during the earthquake. Provision of shear walls makes the structure strong and sustainable to seismic threatening. Position of shear wall plays a vital role in the seismic resistance, it has to be placed in such a way that the overall behaviour of the structure should not be disturbed. Infill wall plays an important role in providing lateral stiffness to the building. In this project an industrial building is selected for the study, to study the seismic performance of soft storey buildings, there are six 3D mathematical models have been developed using ETABS. The following parameters have been studied, storey drift, storey displacement, forces and time period, storey shear, modes shapes. Subsequently adopting the control measures to reduce the effect of soft storey in terms.

Keywords*:* Earthquake, Soft Storey, seismic resistance

I. INTRODUCTION

An Earthquake is a sudden slipping or movement of a portion of the earth's crust or plates, caused by a sudden release of stresses .Earthquake epicenter are usually less than 25 miles below the ear surface and are accompanied and followed by a series of vibrations. The earth has four major layers: The inner core, outer core, mantle and crust. The crust and the top of the mantle make up a thin layer on the surface of earth. But this layer is not a single cover, it is made up of many pieces like jigsaw covering the surface of the earth. These keep slowly moving around each other, slide past one another and bump into each other. These puzzle pieces are called tectonic plates, and the edges of the plates are called the plate boundaries. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur on these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. Finally, when the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake

1. Types of earthquake

Most earthquakes in the world occur along the boundaries of the tectonic plates and are called Inter-plate Earthquakes. A number of earthquakes also occur within the plate itself away from the plate boundaries, called Intra-plate Earthquakes. Earthquakes are recorded by instrument called *seismographs*. The recording they made is called a seismogram.

The seismogram consists of two parts, a base and a weight, to held it firmly in the ground. When an earthquake causes the ground to shake, the base of the seismograph shakes too, but the hanging weight does not. Instead the spring or string that it is hanging from absorbs all the movement. Thus the difference between the moving and immovable part is recorded. The size of an earthquake depends on the size of the fault and the amount of slip on the fault, but this cannot be measured directly as faults are deep in the earth. The seismogram recordings made on the seismographs at the surface of the earth are used to determine the intensity of earthquake.

A short line with less zigzag portions represents a small earthquake and a lengthy line with a lot of zigzag sections shows a large earthquake. The length of line on the seismograph depends on the size of the fault and the wigginess of the line depends upon the amount of slip of the fault.

Earthquake Engineering is the branch of engineering devoted to mitigating earthquake hazards. Earthquake engineering covers the investigation and solution of the problems created by damaging earthquakes, and hence the work involved in the practical application of these solutions in planning, designing, constructing and managing earthquake-resistant structures and facilities.

2. Earthquake environment effects

Earthquake environmental effects are the effects caused by an earthquake on the natural environment, including surface faulting, tectonic uplift and subsidence, tsunamis, soil liquefactions, ground resonance, landslides and ground failure, either directly linked to the earthquake source or provoked by the ground shaking. These are common features produced both in their near and far fields, routinely recorded and surveyed in recent events, very often remembered in historical accounts and preserved in the stratigraphic record (paleoearthquakes). Both surface deformation and faulting and shaking-related geological effects (e.g., soil liquefaction, landslides) not only leave permanent imprints in the environment, but also dramatically affect human structures. Moreover, underwater fault ruptures and seismically-triggered landslides can generate destructive tsunami waves. EEEs represent a significant source of hazard, especially (but not exclusively) during large earthquakes. This was observed for example during more or less catastrophic seismic events recently occurred in very different parts of the world.

3. Soft storey

Reinforced-concrete framed structure in recent time has a special feature i.e. the ground storey is left open for the purpose of social and functional needs like vehicle parking, shops, reception lobbies, a large space for meeting room or a banking hall etc. Such buildings are often called open ground storey buildings or soft story buildings. Again when a sudden change in stiffness takes place along the building height, the story at which this drastic change of stiffness occurs is called a soft story. The Indian code (clause no. 4.20) classifies a soft storey as, It is one in which lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storey above (IS 1893:2002). Soft storey can form at any level of a high rise building to fulfill required functional necessity and serve various. Moreover, typical multistoried construction in India comprises RC frames with brick masonry infill. Unreinforced masonry panels may not contribute towards resisting gravity loads, but contribute significantly, in terms of enhancement in stiffness and strength in case of earthquake (or wind) induced lateral loading. The effect of infill may be positive or negative depending on large number of influential factors

II. LITERATURE REVIEW

Robin Davis, discussed two buildings are located in moderate seismic zone Structurally symmetric (bare frame) is compared to the building with plan and vertical irregularity (soft Storey) Infill wall on the upper floor are modelled using equivalent stiffness strut approach. Equivalent static analysis, response spectrum and Non-linear pushover analysis is performed to determine the structural response of building to earthquake. This study concludes that presence of masonry infill panel considerably increases total storey shear bending moment in the ground floor column and failure occurs due to soft storey mechanism. Hence present structures with soft storey need to be retrofitted.

F. Hejazil (2011), The writer studied seismic behavior of multi-storied building with soft storey by adding bracings to the soft storey. He concluded that, location and number of bracings plays an important factor for soft storey

structure to displace during earthquake The displacement will be smaller of the storey provided with bracings. Also provision of bracing reduces the effect of soft storey and vulnerability to collapse.
Mohammad H. Jinya, V. R. Patel (2014), In this paper seismic behavior of RC frame building is analyzed by performing multi-model static and dynamic analysis. The results of bare frame, masonry infill panel with outer wall opening, and soft storey are discussed. The conclusions made in this study is infill wall(diagonal strut) change the seismic performance of RC building. Storey drift and displacement were decreased. It is suggested that at least soft storey should be provided with outer masonry infill panel to increase stiffness of soft storey.

Md Rihan Maaze, The writer performs equivalent static and response spectrum analysis on infill frame and solid concrete block and compared to bare frame. Also, non-linear pushover analysis is carried out for hinge properties. He concluded that SMRF building models are found more resistant to earthquake loads as compared to OMRF in terms of performance level point and hinge variation. Hence ductile detailing is must for building under high seismic zone.

Dhadde Santosh (2014), The writer carried out the performance evaluation on non-retrofitted buildings. Soft storey is located at ground, intermediate and top and compared to retrofitted model. The performance evaluation was based on lateral deformation, storey shear, and hinge formation From the study, he had concluded that storey drift is maximum at soft storey and it decreases gradually up to the top. Plastic hinge formation, base reaction and roof displacement is more in existing soft storey building but less in retrofitted models.

Hiten L. Kheni, Anuj K.Chandiwala, said collapse mechanism of different buildings damaged under earthquakes are assessed and makes a design concept of strong column weak beam such that during earthquake, beam yield before column collapse. Based on this concept, different building models were analyzed using software. Writer concluded that estimation of displacement of codal lateral load pattern are smaller for lower stories and larger for upper stories and are independent of total number of stories of the model.

Suchita Hirde and Ganga Tepugade, Discussed the performance of a building with soft storey at different level with at ground level. The nonlinear static pushover analysis is carried out Concluded it is observed that plastic hinges are developed in columns of ground level soft storey which is not acceptable criteria for safe design Displacement reduces when the soft storey is provided at higher level.

III. RESULTS AND DISCUSSION

1. General

In this chapter we will discuss about the results which we obtained from ETABS after analyzing the models and results have been given in a tabular form and graphical representation for better understanding.
The Following parameters have been studied and the results are extracted from the computer program.

1) Storey Displacement
2) Storey Drift
3) Base shear
4) Fundamental Time Period
5) Mode shapes.

2. Storey Displacement

Storey displacement is the lateral movement of the structure caused by lateral force. The deflected shape of a structure is most important and most clearly visible point of comparison for any structure. No other parameter of comparison can give a better idea of behavior of the structure than comparison of storey displacement.
The Displacement should be very less in a structure otherwise the structure may collapse

And the total strength will be reduced and there will be no human comfort . It can be seen from above figures, the displacement of the stories of structures is reduced by developing MODEL- 2,3,4,5,6.The displacement in Model-2

Has been reduced by 57.5 % in comparison of Model-1, Model-3 has been reduced to75.5%.Model-4 has been reduced by 81.4%, Model-5 has been reduced by 78.4%, Model-6 has been reduced by 82.4%.

According to this work, the reduction of displacement of stories is due to increase of stiffness of structure as well as decrease of velocity and acceleration of structure. In other words by creating theMODEL-2, 3,4,5,6 the response of structure such as velocity and acceleration can be reduced and it is the cause of reduction of displacement.

On Observing, displacements at the entire storey in the MODEL-1 are more than those in Other model. Here as one can see displacements lowest in bottom stories, very high at the upper stories. The displacement is of interest with regard to structural stability, strength and human comfort. The displacement of MODEL-1is more than the other model. It means that Structure is more stable Chance of Structural Strength reduction is less. Human comfort is good.

3. Storey Drift

Storey drift is the drift of one level of a multistory building relative to the level below. Inter story drift is the difference between the roof and floor displacements of any given story as the building sways during the earthquake, normalized by the story height. For example, for a 10foot high story, an inter-story drift of 0.10 indicates that the roof is displaced one foot in relation to the floor below.

The greater the drift, the greater the likelihood of damage. Peak inter story drift values larger than 0.06 indicate severe damage, while values larger than 0.025 indicate that the damage could be serious enough to pose a serious threat to human safety. Values in excess of 0.10 indicate probable building collapse. According to I.S 1893 -2002 permissible storey drift is equals to 0.004 times height of storey

As it can seen from the above figures that the storey drifts has been reduced in Models 1, 3,4,5,6. The storey drift has been reduced in Model-1 by 38.7% in comparison of model-2, Model-3 has been reduced by 64.6%, Model-4 has been reduced by 77.8%, Model-5 has been reduced by 74.3%, and Model-6 has been reduced by 82% .Furthermore the graph shows that there has been steady decreasing in the amount of story shear over the height. In all models, the story shear at the base is more and at the top story shear is less. But when we compare All models, the minimum story shear is in MODEL-1, 3,4,5,6 and maximum is in MODEL-2.

4. Base shear

Shear induced at the base of building during earthquake is called base shear which depends on the seismic mass and stiffness of building. The results of variation in Base Shear due to the effect of earth quakes for different cases are tabulated below:

As it can seen from below figure, the base shear has been reduced in Models-1, 2,3,4,5. The Base shear has been reduced by 78% in comparison of model-6,Model-2 has been reduced by 65.4%, Model-3 has been reduced by 31.5%,Model-4 has been reduced by 6%, Model-5 Has been reduced by 24.31%.Model-6 has maximum base shear where Model-1,2,3,4,5 has less Base shear.Model-1 has minimum base shear.

5. Fundamental time period:

Fundamental time period is the time taken by the building to undergo a cycle of to and fro movement. The fundamental time period determined for building is as follows:

The value of T depends on the building flexibility and mass; more the flexibility and mass, the longer is the period. The maximum time period is in MODEL-1 and minimum time period is in MODEL-6. Therefore one can say that MODEL-6 has more flexibility and mass when compared to other models

Table 5.1: Displacement in longitudinal Direction

STOREY LEVEL	MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
10	16.1632	7.7052	4.6159	3.6053	4.0489	3.434
9	15.6954	7.6002	4.4087	3.4463	3.8154	3.2478
8	14.9384	7.493	4.1912	3.2734	3.5673	3.0441
7	13.9228	7.3813	3.9641	3.0875	3.3083	2.8251
6	12.6799	7.2657	3.7288	2.8905	3.0403	2.5933
5	11.2343	7.1465	3.4868	2.6849	2.7656	2.3519
4	9.6098	7.0246	3.2402	2.4731	2.4869	2.1045
3	7.8257	6.9005	2.9912	2.2583	2.2074	1.855
2	5.8854	6.7777	2.7436	2.0442	1.9313	1.6084
1	3.7072	6.6397	2.4909	1.8286	1.6549	1.3643

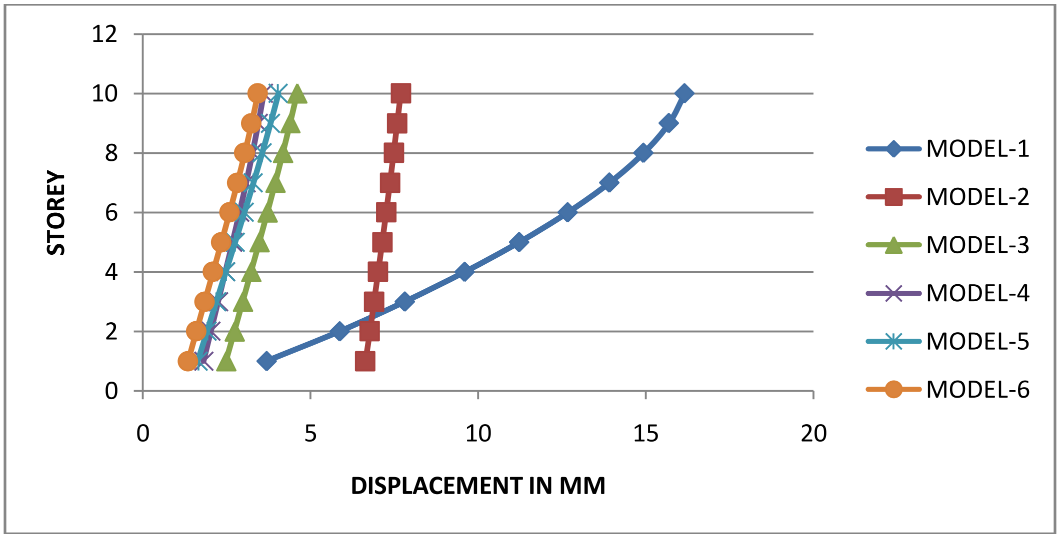

Fig 5.1: Displacement in Longitudinal Direction

Table 5.2: Displacement in Transverse Direction

STOREY LEVEL	MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
10	20.3612	7.6257	4.156	3.0586	3.7312	2.8396
9	19.7889	7.5423	4.0261	2.8758	3.5233	2.6555
8	18.885	7.4559	3.8894	2.6818	3.3067	2.4594
7	17.642	7.3664	3.746	2.4774	3.0823	2.2521
6	16.0941	7.2742	3.597	2.2647	2.8515	2.0362
5	14.2755	7.1796	3.4433	2.0462	2.6162	1.8143
4	12.2146	7.0834	3.2864	1.8246	2.3785	1.5893
3	9.9356	6.9848	3.1272	1.603	2.141	1.3647
2	7.4536	6.8897	2.9693	1.3852	1.9073	1.1448
1	4.6363	6.7784	2.8069	1.168	1.6788	0.9278

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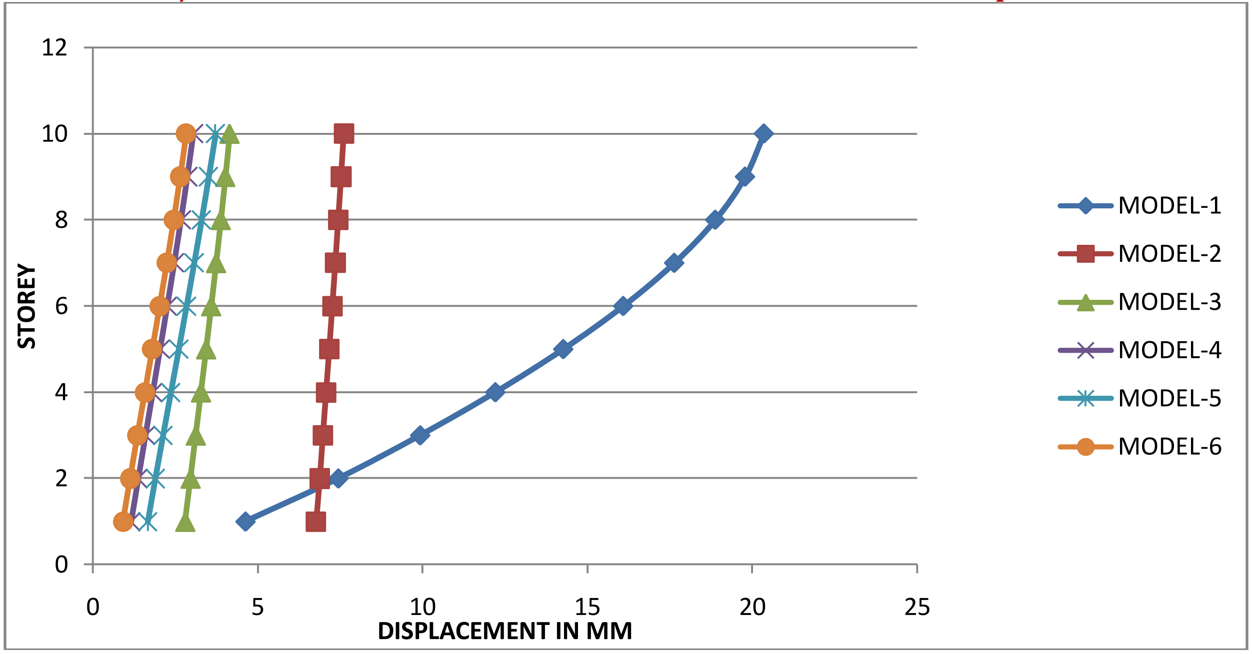

Fig 5.2: Displacement in Transverse Direction

Table5.3: Storey Drift in Longitudinal Direction

STOREY LEVEL	MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
10	0.000228	0.000035	0.00007	0.000054	0.000079	0.000063
9	0.000378	0.000036	0.000074	0.000059	0.000084	0.000069
8	0.000497	0.000038	0.000077	0.000064	0.000088	0.000074
7	0.000582	0.000039	0.00008	0.000068	0.000091	0.000079
6	0.000653	0.00004	0.000083	0.000071	0.000094	0.000082
5	0.000716	0.000041	0.000085	0.000073	0.000095	0.000084
4	0.000767	0.000042	0.000085	0.000074	0.000096	0.000085
3	0.000813	0.000042	0.000085	0.000074	0.000095	0.000083
2	0.0009	0.000047	0.000086	0.000075	0.000094	0.000082
1	0.001026	0.001893	0.000554	0.000409	0.000496	0.000339

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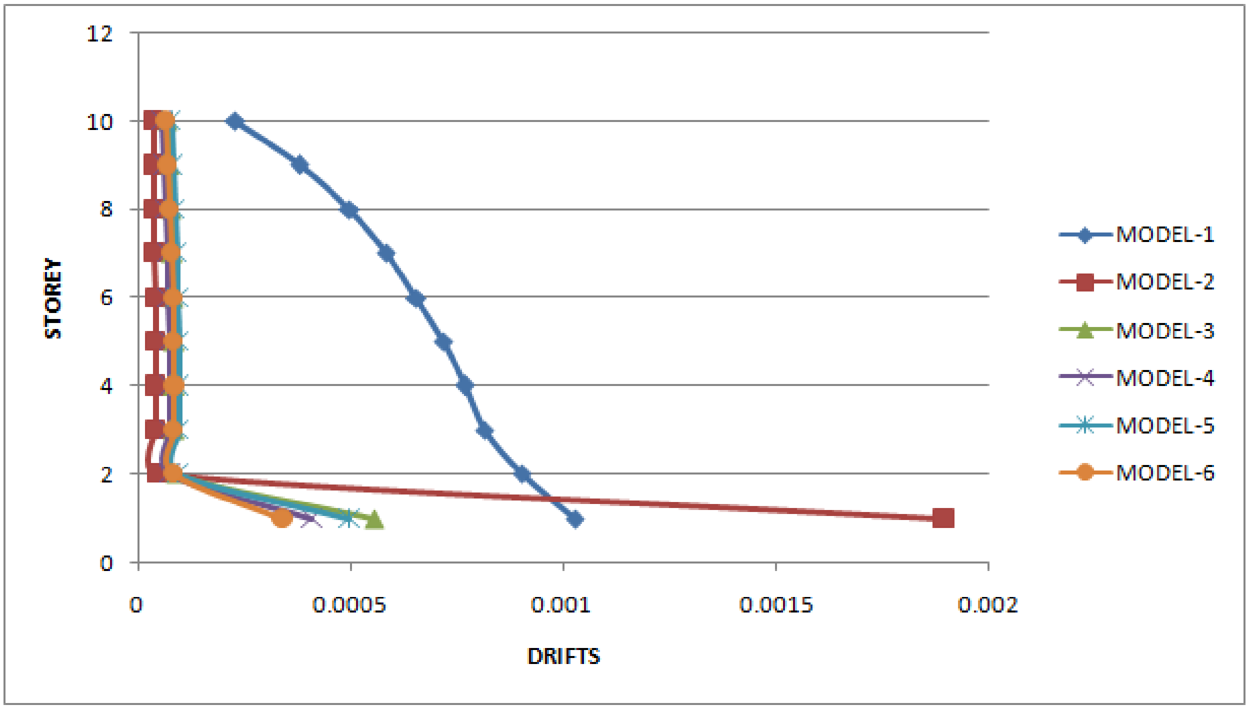

Fig 5.3: Drift in Longitudinal Direction

Table 5.4: Storey Drift in Transverse direction

STOREY LEVEL	MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
10	0.000236	0.000028	0.000044	0.000062	0.00007	0.000062
9	0.000374	0.000029	0.000046	0.000067	0.000073	0.000067
8	0.000492	0.00003	0.000048	0.000071	0.000075	0.000072
7	0.000588	0.000031	0.00005	0.000074	0.000078	0.000075
6	0.000668	0.000032	0.000052	0.000077	0.000079	0.000078
5	0.000734	0.000032	0.000053	0.000079	0.00008	0.00008
4	0.000794	0.000033	0.000053	0.000079	0.00008	0.00008
3	0.000847	0.000032	0.000053	0.000079	0.000079	0.000079
2	0.000944	0.000037	0.000055	0.000078	0.000077	0.000078
1	0.00103	0.001506	0.000625	0.000344	0.000375	0.000275

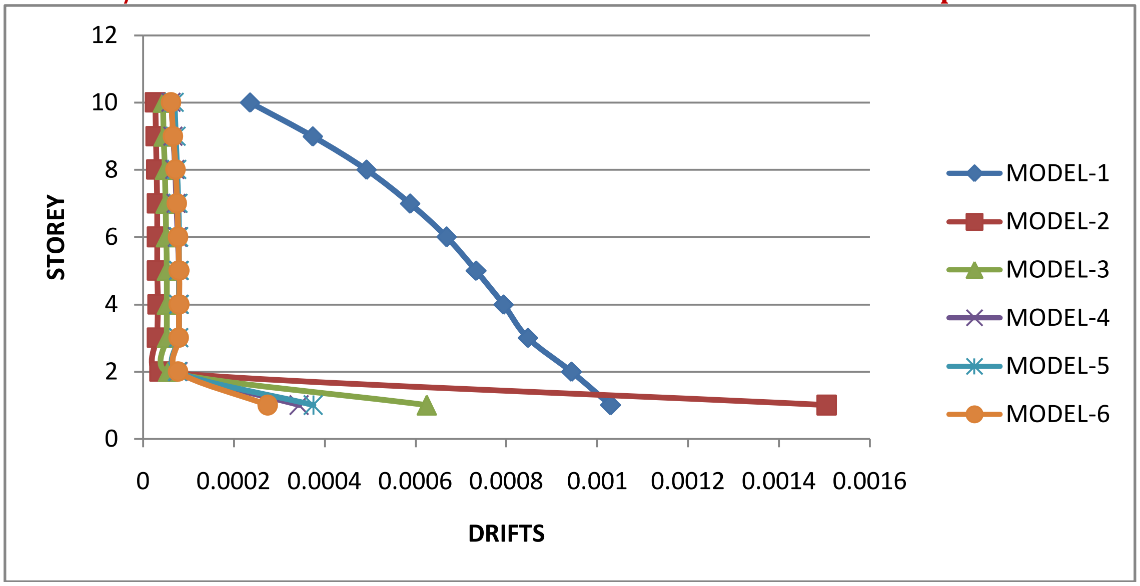

Fig 5.4: Storey Drift in Transverse Direction

Table 5.5: Base shear in KN in Longitudinal Direction.

STOREY LEVEL	MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
10	72.06	59.81	142.77	186.52	171.81	220.96
9	153.89	132.4	310.4	404.81	368.94	479.7
8	210.63	202.82	464.82	607.46	545.78	715.94
7	250.36	271.22	606.51	794.48	703.12	929.7
6	285.9	337.81	736.43	966.55	842.73	1122.03
5	319.84	402.86	856.01	1124.79	967.16	1294.64
4	348.15	466.67	966.86	1270.57	1079.35	1449.63
3	373.2	529.53	1070.69	1405.28	1182.22	1588.98
2	401.34	591.71	1169.01	1530.13	1278.25	1714.34
1	428.67	641.85	1246.19	1627.96	1352.93	1810.59

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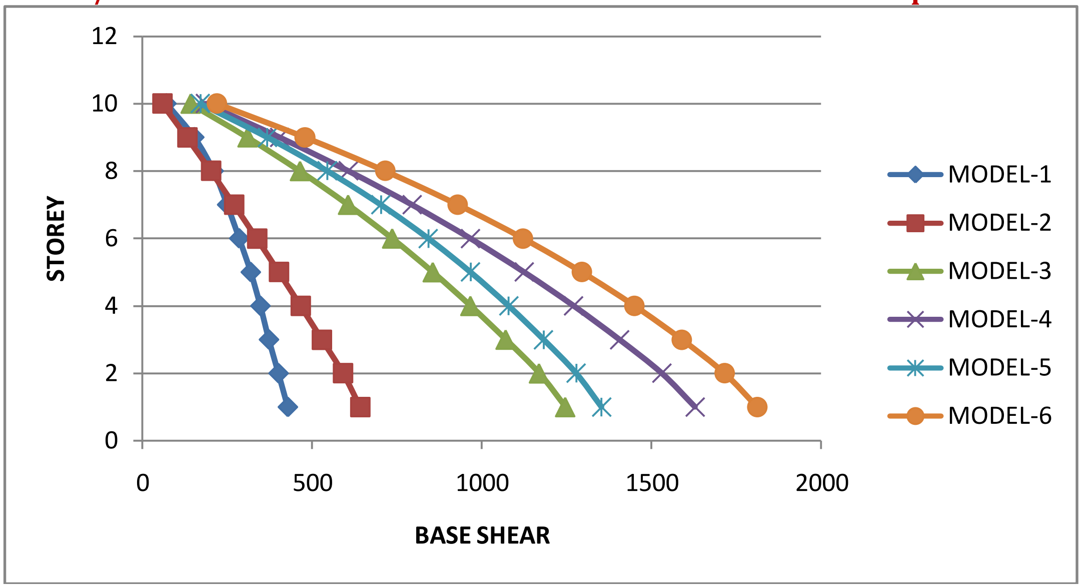

Fig 5.5: Base shear in Longitudinal Direction

Table 5.6: Base shear in KN in Transverse Direction

STOREY LEVEL	MODEL-1	MODEL-2	MODEL-3	MODEL-4	MODEL-5	MODEL-6
10	69.24	59.84	136.42	242.05	181.65	252.29
9	140.66	133.21	301.13	520.27	392.79	544.67
8	189.7	205.18	457.77	773.3	585.57	808.74
7	230.87	275.81	606.51	1001.48	760.52	1044.75
6	266.47	345.22	747.75	1206.14	918.79	1254.16
5	296.74	413.51	882.04	1389.29	1062.06	1439.19
4	325.74	480.83	1010.06	1553.26	1192.3	1602.33
3	351.1	547.31	1132.46	1700.31	1311.56	1745.99
2	374.45	613.09	1249.91	1832.37	1421.76	1872.1
1	398.23	666.1	1343.1	1931.94	1506.75	1965.86

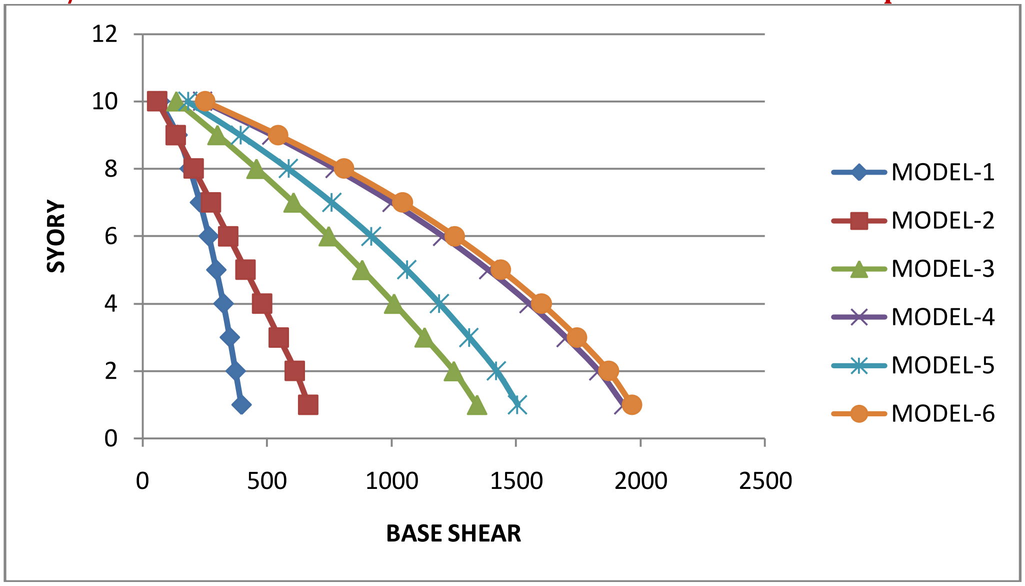

Fig 5.6: Base shear in Transverse Direction

Table 5.7: Time period in Seconds

MODELS	MODE-1	MODE-2	MODE-3
1	0.5972	0.5731	0.5935
2	0.3471	0.3188	0.3096
3	0.2846	0.2589	0.2443
4	0.2443	0.2233	0.1667
5	0.2316	0.2233	0.1902
6	0.2012	0.1978	0.1578

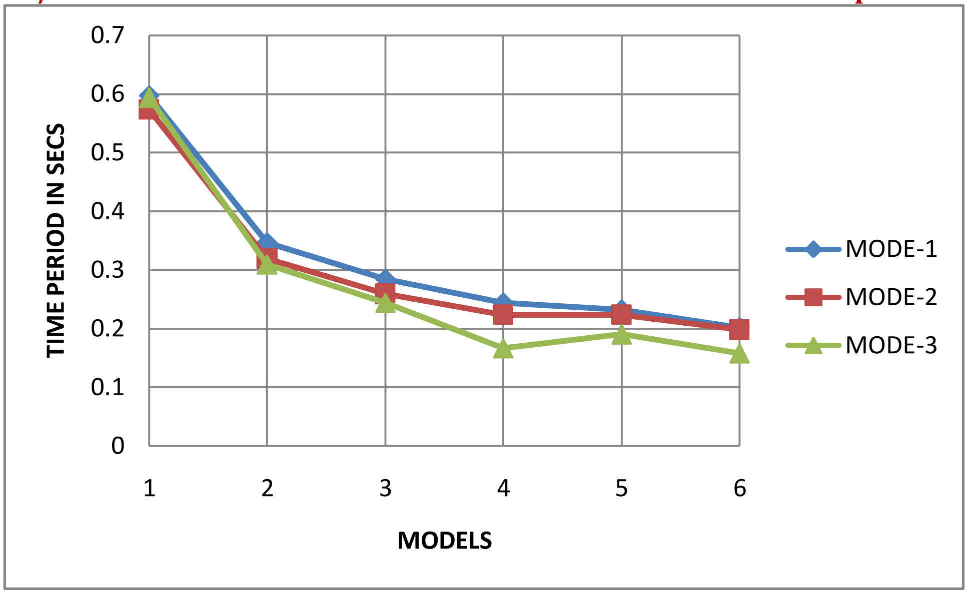

Fig 5.7: Time period

IV. CONCLUSION

1. Model-1 shows highest time period and lowest base shear, it indicates it has got least stiffness as compare to other five Models.
2. Model with bottom soft storey shows highest storey drift at ground level as compare to other models , it shows that bottom soft storey has got lesser stiffness as compare to above stories , therefore soft storey is dangerous at lower level, so that any suitable provision should be made so as to avoid the catastrophic or sudden collapse.
3. When we compare bare frame model with other models, it shows highest storey displacements t top storey, when we add planar or L- shaped shear wall displacement got reduced considerably hence provision of shear wall reduces storey displacements and make the structure stiff .
4. When we compare Model-II with other four models it shows least stiffness , therefore provision of shear walls will make the structure strong and sustainable to seismic threatening.
5. Model without core wall showing same behavior with central core wall models hence core walls should be provided in the models to nearest of centre of mass point.
6. Position of shear wall plays a very vital role in the seismic resistance, it has to be placed in such a way that the overall behavior of the structure should not be disturbed.
7. Mode shapes study shows that, Model-II shows higher torsion at ground storey as compare with other models.
8. When we don't consider the importance of masonry infill panels in modeling and designing , it considerably effect the overall behavior of the structure , it may leads form the soft storey, as reveal by the results